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**What is claimed is:**

1. In a method for making a transfer medium defining a pattern to be transferred lithographically to a sensitive substrate using a charged particle beam passing through a charged-particle-beam (CPB) optical system, a method for correcting proximity effects, comprising:
  - (a) dividing the pattern into multiple subfields to be exposed onto the substrate in respective shots of the charged particle beam, each subfield containing one or more respective elements of the pattern;
  - 10 (b) for selected subfields, determining data concerning beam blur that would be imposed by the CPB optical system exposing the respective subfields, the blur for a selected subfield being a function of beam deflection to expose the subfield and of location of one or more pattern elements within the subfield;
  - (c) storing the data for the selected subfields; and
  - 15 (d) configuring the pattern on a reticle, wherein, for each of the selected subfields, the data is recalled and used in local resizing of the respective elements in the subfields so as to achieve a reduction of proximity effects in the subfield as transferred to the substrate.
- 20 2. The method of claim 1, wherein the data is stored as at least one respective table for each selected subfield.
3. The method of claim 1, wherein the data is stored as at least one respective equation for each selected subfield.
- 25 4. The method of claim 1, wherein the data is different for each of the selected subfields.
5. A transfer medium, fabricated by a method as recited in claim 1.

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6. A recording medium, comprising a computer program for implementing the method of claim 1.

5 7. A method for performing charged-particle-beam microlithography, comprising the steps of:

(a) providing a transfer medium as recited in claim 1; and

(b) projecting the pattern defined by the transfer medium onto a sensitive substrate using a charged particle beam passing through the CPB optical system.

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8. A microelectronic-device fabrication process, comprising the steps of:

(a) preparing a wafer;

(b) processing the wafer; and

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(c) assembling devices formed on the wafer during steps (a) and (b),

wherein step (b) comprises a method for performing microlithography as recited in claim 7.

20 9. In a charged-particle-beam (CPB) microlithography method in which a pattern defined by a reticle is projection-exposed onto a resist-coated surface of a substrate using a charged particle beam as an energy beam, a method for correcting a proximity effect, resulting from backscattering of charged particles in the resist-coated substrate, by correcting pattern-element exposure data including data on radiation dose as well as respective profiles, edge positions, and dimensions of  
25 pattern elements, so as to adjust respective positions of edges of the pattern elements as defined on the reticle, the method comprising:

(a) determining blur of the charged particle beam irradiating the substrate, the blur being a function of beam deflection and respective locations of pattern elements within an area of the pattern exposed in a respective shot;

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(b) from the determined blur, calculating preliminarily corrected pattern-element exposure data;

(c) at one or more edges of a pattern element as exposed onto the substrate, calculating exposure dose, as affected by backscattering, of the pattern element as  
5 defined by the preliminarily corrected pattern-exposure data;

(d) from the determined blur and calculated exposure dose, calculating a distribution of exposure dose in the vicinity of pattern-element edges as projected onto the substrate;

(e) from the calculated distribution of exposure dose, determining a dose  
10 threshold value;

(f) predicting, from the determined dose threshold value and the calculated distribution of exposure dose, positions of pattern-element edges that actually will be formed on the substrate; and

(g) from the predicted positions of pattern-element edges, adjusting the  
15 pattern-element edge positions as defined on the reticle to cause the pattern-element edges as projected to be situated in respective prescribed locations on the substrate.

10. The method of claim 9, wherein in step (g) the edge positions of pattern elements as projected onto the substrate are adjusted to the respective  
20 prescribed locations by making corresponding changes to pattern-element edge-position data in the pattern-element exposure data.

11. The method of claim 9, wherein in step (g) the edge positions of pattern elements as projected onto the substrate are adjusted to the respective  
25 prescribed locations by making corresponding changes to radiation-dose data in the pattern-element exposure data.

12. The method of claim 9, wherein step (c) comprises:

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in a pattern region having a dimension substantially similar to a diameter of backscatter from an edge of the pattern element, defining a grid for dividing the pattern region into sub-regions containing respective portions of the pattern element, the sub-regions having dimensions that are from 1/100 to 1/3 the backscatter

5 diameter;

within a sub-region, defining the pattern-element portion by a corresponding representative figure; and

calculating the exposure dose, as affected by backscattering, based on the representative figure.

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13. The method of claim 12, wherein:

determining blur includes determining a difference of blur from another location on the pattern from maximal blur for the pattern; and

15 a correction is made, from doses contributed by proximity effects and slopes of edges of projected pattern elements, such that, at a prescribed dose threshold, the edges of the pattern elements are projected at their respective prescribed locations on the substrate.

14. The method of claim 13, wherein the slopes of edges of the projected  
20 pattern element having a width of no greater than four times the blur are obtained from a stored data table or from a stored equation in which blur is a function of linewidth of the pattern element as projected.

15. The method of claim 13, wherein blur has a value that is a function of  
25 magnitude of deflection of the charged particle beam incident to the substrate, or location within a transverse profile of the beam, or both.

16. The method of claim 9, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 40 keV.

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17. The method of claim 16, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 50 keV.

5 18. The method of claim 17, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 70 keV.

19. In a charged-particle-beam (CPB) microlithography method in which a pattern defined by a reticle is projection-exposed onto a resist-coated surface of a substrate using a charged particle beam, a method for correcting the reticle at time of reticle fabrication so as to correct proximity effects that otherwise would arise from backscattering of charged particles in the resist-coated substrate, by correcting pattern-exposure data including data on radiation dose and respective profiles and dimensions of pattern elements, so as to adjust respective positions of edges of the pattern elements as defined on the reticle, the method comprising:

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(a) determining blur of the charged particle beam irradiating the substrate, the blur being a function of beam deflection and respective locations of pattern elements within an area of the pattern exposed in a respective shot;

(b) at one or more edges of a pattern element as exposed onto the substrate, calculating exposure dose, as affected by backscattering, of the pattern element;

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(c) from the determined blur and the calculated exposure dose, calculating a distribution of exposure dose in the vicinity of pattern-element edges as projected onto the substrate;

(d) from the calculated distribution of exposure dose, determining a dose threshold value;

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(e) predicting, from the determined dose threshold value and the calculated exposure dose, positions of pattern-element edges that actually will be formed on the substrate; and

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(f) from the predicted positions of pattern-element edges, adjusting the pattern-element edge locations to be defined on the reticle to cause the pattern-element edges as projected to be situated in respective prescribed locations on the substrate.

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20. The method of claim 19, wherein locations of edges of pattern elements as will be formed on the substrate by projection of the pattern on the reticle are adjusted to be at their prescribed locations on the substrate by changing corresponding pattern-element profile and dimensional data used for fabricating the reticle.

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21. The method of claim 19, wherein locations of edges of pattern elements as will be formed on the substrate by projection of the pattern on the reticle are adjusted to be at their prescribed locations on the substrate by changing radiation-dose data corresponding to the pattern-element data as used for fabricating the reticle.

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22. The method of claim 19, wherein step (b) comprises:  
in a pattern region having a dimension substantially similar to a diameter of backscatter from an edge of the pattern element, defining a grid for dividing the pattern region into sub-regions containing respective portions of the pattern element, the sub-regions having dimensions that are from 1/100 to 1/3 the backscatter diameter;

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within a sub-region, defining the pattern-element portion by a corresponding representative figure; and

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calculating the exposure dose, as affected by backscattering, based on the representative figure.

23. The method of claim 22, wherein:

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determining blur includes determining a difference of blur from another location on the pattern from maximal blur for the pattern; and

a correction is made, from doses contributed by proximity effects and slopes of edges of projected pattern elements, such that, at a prescribed dose threshold, the  
5 edges of the pattern elements are projected at their respective prescribed locations on the substrate.

24. The method of claim 23, wherein the slopes of edges of the projected pattern element having a width of no greater than four times the blur are obtained  
10 from a stored data table or from a stored equation in which blur is a function of linewidth of the pattern element as projected.

25. The method of claim 23, wherein blur has a value that is a function of magnitude of deflection of the charged particle beam incident to the substrate, or  
15 location within a transverse profile of the beam, or both.

26. The method of claim 19, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 40 keV.

20 27. The method of claim 26, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 50 keV.

28. The method of claim 27, wherein the charged particle beam incident to the substrate is an electron beam accelerated to at least 70 keV.

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29. A reticle for use in charged-particle-beam (CPB) microlithography, fabricated by a method including the proximity-effect correction method of claim 9.

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30. A reticle for use in charged-particle-beam (CPB) microlithography, fabricated by a method including the proximity-effect correction method of claim 19.

31. In a charged-particle-beam (CPB) microlithography method in which  
5 a pattern defined by a reticle is projection-exposed onto a resist-coated surface of a substrate using a charged particle beam, a method for producing a reticle defining pattern elements configured so as to correct proximity effects in the pattern as projected onto the resist-coated surface, the method comprising:
- 10 (a) producing data for a primary reticle pattern as defined on a segmented reticle comprising subfields each defining a respective portion of the reticle pattern to be exposed onto the substrate in a respective shot;
  - (b) for each subfield, and according to the primary-reticle-pattern data, determining a distribution of blur at the substrate that would exist if the pattern, as defined by the primary reticle pattern, were projected onto the substrate;
  - 15 (c) from the determined distribution of blur from the primary reticle pattern, determining a distribution of beam energy that would exist at the substrate for each projected subfield;
  - (d) from the determined distribution of beam energy as projected on the substrate for each subfield, determining a distribution of exposure energy in the  
20 resist-coated substrate for each subfield, taking into account proximity effects and backscattering of the beam in the resist-coated substrate;
  - (e) from the determined distribution of exposure energy, determining a dose threshold for each subfield;
  - (f) from the determined distribution of exposure energy and dose threshold,  
25 producing data defining locations of edges of pattern elements in the respective pattern portion defined by each subfield so that, when the respective pattern portions are projected, the pattern elements will form at desired respective locations with desired profiles on the resist-coated substrate; and
  - (g) from the data produced in step (f), fabricating the reticle.

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32. In a charged-particle-beam (CPB) microlithography method in which a pattern defined by a reticle is projection-exposed onto a resist-coated surface of a substrate using a charged particle beam, a method for producing a reticle defining pattern elements configured so as to correct proximity effects in the pattern as projected onto the resist-coated surface, the method comprising:

- (a) producing data on a primary reticle pattern as divided into subfields each defining a respective portion of the pattern to be projected onto a the substrate in respective shots;
- 10 (b) determining a distribution of beam blur as a function of beam deflection for irradiating a given subfield of the primary reticle pattern and of a distribution of pattern elements within the given subfield;
- (c) storing data regarding the determined distribution of beam blur;
- (d) determining a beam-energy profile at the substrate exposed with the  
15 primary reticle pattern;
- (e) recalling the data regarding the distribution of beam blur and determining a cumulative exposure-energy distribution at the substrate exposed with the primary reticle pattern, taking into account proximity effects in the exposed primary reticle pattern and the data on the distribution of beam blur;
- 20 (f) from the determined distribution of cumulative exposure energy, determining a dose threshold;
- (g) at the dose threshold, calculating edge locations of pattern elements of the primary reticle pattern as projected;
- (h) based on the calculated edge locations, correcting the primary pattern  
25 data so that edge locations correspond to respective edge locations according to design specifications, the corrections being made by local resizing of pattern elements, by local dose corrections, or both; and
- (i) based on the corrected pattern data, fabricating the reticle.

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33. The method of claim 32, wherein the distribution of beam blur is determined as a mathematical function that is stored.

34. The method of claim 32, wherein the distribution of beam blur is  
5 determined as a data table that is stored.

35. The method of claim 32, wherein the distribution of blur is calculated as an isotropic distribution.

10 36. The method of claim 32, wherein the distribution of blur is calculated as an anisotropic distribution.

37. The method of claim 32, wherein the calculation of edge locations of pattern elements as projected includes taking into consideration the distribution of  
15 beam blur.

38. The method of claim 32, wherein the correction to the primary reticle pattern data includes taking into consideration a dose level and slope of the corresponding beam-energy distribution at the substrate.

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39. The method of claim 38, wherein correcting the primary reticle data by taking into consideration the dose level and slope of the corresponding beam-energy distribution at the substrate comprises:

25 of the primary pattern, dividing a selected pattern portion into subregions each containing a respective portion of a pattern element;

representing the pattern-element portion in each subregion as a respective representative figure having an area equal to an area of the respective pattern-element portion;

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with respect to each representative figure, calculating fogging due to backscattering; and

from the calculated fogging for individual subregions, calculating fogging for the element in the selected pattern portion.

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40. The method of claim 39, further comprising the step of calculating, based on data regarding fogging for the pattern element, a distribution of exposure energy at the edges of the pattern element.

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41. The method of claim 40, further comprising the step of calculating slopes of the exposure-energy distribution at the edges of the pattern element.

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42. The method of claim 41, wherein the primary pattern data are corrected to a degree determined from the calculated slopes of exposure-energy distribution.

43. A reticle for use in charged-particle-beam (CPB) microlithography, produced by the method of claim 31.

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44. A reticle for use in charged-particle-beam (CPB) microlithography, produced by the method of claim 32.

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45. In a charged-particle-beam (CPB) microlithography method in which a pattern defined by a reticle is projection-exposed by a projection-optical system onto a resist-coated surface of a substrate using a charged particle beam as an energy beam, a method for correcting a proximity effect, resulting from backscattering of charged particles in the resist-coated substrate, by correcting pattern-exposure data including data on radiation dose and respective profiles and dimensions of pattern

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elements, so as to adjust respective positions of edges of the pattern elements as defined on the reticle, the method comprising:

- (a) defining a design pattern to be formed on the resist-coated substrate;
- (b) obtaining a primary reticle pattern by enlarging the design pattern by the reciprocal of a demagnification ratio of the projection-exposure system;
- (c) calculating an energy profile  $DW(x)$  of the charged particle beam that would exist at the resist-coated substrate after passage through the primary reticle pattern and through the projection-optical system, the calculation of  $DW(x)$  taking into account a reduction of energy at the substrate due to blur of the charged particle beam during passage through the projection-optical system;
- (d) calculating a profile  $E(x)$  of cumulative exposure energy due to backscatter occurring at the resist-coated substrate being irradiated by a charged particle beam having the energy profile  $DW(x)$ ;
- (e) for an energy profile that is a sum of  $DW(x)$  and  $E(x)$ , setting a development-energy threshold for the pattern elements as projected from the primary reticle pattern;
- (f) calculating widths of pattern elements that would be formed on the resist-coated substrate exposed with the charged particle beam from the primary reticle pattern; and
- (g) from the calculated widths of pattern elements, correcting the primary reticle pattern to form a for-projection pattern that will produce linewidths according to the design pattern, wherein corrections are made to individual pattern elements as defined on the reticle, taking into account the beam blur versus location of edges of the respective pattern elements within an area to be exposed in a single shot.

46. A reticle for use in charged-particle-beam (CPB) microlithography, fabricated by a method including the proximity-effect correction method of claim 45.

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52. A microelectronic-device fabrication process, comprising the steps  
of:

- 5 (a) preparing a wafer;  
(b) processing the wafer; and  
(c) assembling devices formed on the wafer during steps (a) and (b),  
wherein step (b) comprises a method for performing microlithography as recited in  
claim 47.

10 53. A microelectronic-device fabrication process, comprising the steps  
of:

- (a) preparing a wafer;  
(b) processing the wafer; and  
(c) assembling devices formed on the wafer during steps (a) and (b),  
15 wherein step (b) comprises a method for performing microlithography as recited in  
claim 48.

54. A microelectronic-device fabrication process, comprising the steps  
of:

- 20 (a) preparing a wafer;  
(b) processing the wafer; and  
(c) assembling devices formed on the wafer during steps (a) and (b),  
wherein step (b) comprises a method for performing microlithography as recited in  
claim 49.

25 55. A microelectronic-device fabrication process, comprising the steps  
of:

- (a) preparing a wafer;  
(b) processing the wafer; and

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58. The method of claim 57, wherein the blur data is stored as a data table.

59. The method of claim 57, wherein the blur data is stored as a  
5 mathematical function.

60. The method of claim 57, wherein the blur data differ from subfield to subfield of the pattern.

10 61. A computer-readable medium, comprising as computer program for executing the method of claim 57.

62. A proximity-effect-corrected segmented reticle produced by a method comprising the method of claim 57.  
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63. A method for performing charged-particle-beam microlithography, comprising the steps of:  
(a) providing a reticle as recited in claim 62; and  
(b) projecting the pattern defined by the reticle onto a sensitive substrate  
20 using a charged particle beam.

64. A microelectronic-device fabrication process, comprising the steps of:  
(a) preparing a wafer;  
25 (b) processing the wafer; and  
(c) assembling devices formed on the wafer during steps (a) and (b),  
wherein step (b) comprises a method for performing microlithography as recited in claim 63.